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by

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16. ABSTRACT

Humans consume lead by inhaling air, drinking beverages, eating food, and ingesting dust. Major anthropogenic sources are atmospheric lead, metallic lead (primarily solder), and lead in paint pigments. The weathering products of parent rock material during soil formation are natural sources of lead and enter the food chain dissolved in soil moisture taken up by plants.

This paper evaluates human exposure to lead at a baseline level for persons living in non-urban communities away from stationary or mobile sources of lead, eating typical diets, and engaging in no lead-related occupational or avocational activities. Relative contributions of atmospheric and metallic lead are evaluated for each exposure pathway. For this baseline situation, perhaps 40 to 55% of the total human exposure to lead is of atmospheric origin.

Beyond the baseline level, additional exposure factors can be determined for other environments (e.g. urban, occupational, smelter communities) and for certain habits and activities (e.g. pica, smoking, drinking, and various hobbies), with variations for age, sex, or socioeconomic status. Although quantification of these factors is uncertain, they provide guidelines in determining relative exposures under differing environmental conditions. The added exposure factors can also be partitioned into atmospheric, metallic, and pigment lead.

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ABSTRACT

The pathways of human exposure to lead involve food, inhaled lead, dusts of various types, and drinking water. The major anthropogenic contributions to these pathways are atmospheric lead, metallic lead (primarily solder), and lead in paint pigments. Natural sources of lead, derived from the weathering products of parent rock material during soil formation, eventually enter the human food chain dissolved in soil moisture taken up by plants.

This paper evaluates human exposure to lead at a baseline level, where the person is living in a non-urban community not proximate to stationary or mobile sources of lead, eats a typical diet, and engages in no lead-related occupational or avocational activity. It would be virtually impossible for this person to reduce his level of exposure without extraordinary changes in lifestyle. For each exposure pathway, the relative contributions of atmospheric and metallic lead are evaluated. It appears that for this baseline situation, 40 to 55% of the total human exposure to lead is of atmospheric origin.

Beyond the baseline level, additional exposure factors can be determined for other environments (e.g. urban, occupational, smelter communities), for certain habits and activities (e.g. pica, smoking, drinking, and various hobbies), and for variations due to age, sex, or socioeconomic status. Although these factors are not quantified with great certainty, they are useful guidelines in determining relative exposures under differing environmental conditions. As with the baseline estimates, the added exposure factors can be partitioned into atmospheric, metallic, and pigment lead.

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INTRODUCTION

This paper addresses the question of the total exposure of humans to lead, and the question of the sources of this exposure. It is a brief summary of Chapter 7 of the Air Quality Criteria for Lead document as it appears in its present external review draft form (1). Chapter 7 deals with environmental concentrations and potential pathways to human exposure. The chapter has been reviewed by a panel of experts, and further changes are expected following the public comment period and subsequent review by the Clean Air Science Advisory Committee.

The total exposure of humans to an air pollutant involves more than just the inhalation of that pollutant and retention of particles by lung tissue. Entry of atmospheric pollutants may be by several other routes. Dust may be consumed directly or with food and water. Atmospheric particles may be deposited by wet or dry deposition on food crops or during food processing. For lead, dusts of various types are a primary source of lead consumption in the cases of lowest exposure, and the major source for the special cases of urban and occupational exposure. The significance of this point is that because dusts have a far longer lifetime in the environment than airborne particles, changes in human exposure that might be expected from changes in air concentrations would probably be delayed somewhat as the dust itself is cycled out of the human environment.

Regulatory decisions that relate ambient air quality to human health require the best estimate of the total human exposure to a pollutant and the best description of the effects of this exposure on humans. When there are multimedia sources of a pollutant, it is important to that decision that the fraction of total exposure derived from the atmosphere be known. Because atmospheric lead in dust mixes readily with dust from soil and painted surfaces, and from lead in metal alloys, it is extremely difficult to isolate the sources of anthropogenic lead. Separation of the environmental exposure components into their atmospheric and non-atmospheric components has become technically feasible only because of recent measurements of atmospheric dry deposition rates and food crop concentration using high quality clean lab techniques. These are the critical measurements. In the context of less rigorous measurements of lead in air, soil, and food products, a somewhat complete but tentative picture emerges of the minimum and probable maximum fraction of the total human lead exposure that can be attributed to atmospheric lead in dust, food, and water.

Exposure is defined here as the total amount of lead that enters the body through the mouth or nasal passages. No attention is given to the rate of absorption across the intestinal or alveolar surfaces. Because the particle size range is such that most inhaled particles are trapped and swallowed, the amount of lead exhaled is considered insignificant. Consequently, the problem becomes one of determining the lead concentrations in air, food, water, and dust, and the amounts of each consumed by humans.

The approach used in developing this concept for the Air Quality Criteria for Lead document was to determine a baseline exposure level for a typical American, then extrapolate from that baseline for various scenarios of potential lead exposure. The baseline exposure level was taken to be non-urban ambient air not directly influenced by smelter or roadway emissions, no primary (worker) or secondary (worker's family) occupational exposure, and normal supermarket food. It is likely that further reductions in exposure under present conditions would not be possible without profound changes in lifestyle.

Using the available food consumption data, it is possible to estimate exposures of several age groups from infant to elderly. For brevity, however, only the baseline and extended exposures of 2-year-old children will be discussed here.

It is necessary to make several informed assumptions in producing this exposure estimate. Because it is not always possible to give a full explanation for these assumptions, the reader should refer to the criteria document for such explanations. One such assumption is that deposition of lead bearing particles occurs on all exposed surfaces as a function of air concentrations, particle size distributions and air mass parameters related to windspeed. For this report, air concentrations alone are considered, as the other parameters do not change the deposition rates sufficiently to affect the limited discussions of this paper.

The concept of dust itself is poorly defined. The common notion that only gravitational particles accumulate on upfacing horizontal surfaces is inadequate. Dusts originate from the disintegration of larger particles or the agglomeration of smaller particles. They may accumulate on exposed surfaces of any orientation.

BASELINE EXPOSURE

Food crops and dust account for 80 percent of the baseline exposure of young children. To estimate the baseline exposure in each category, it is necessary to make a few simplifying assumptions. For food crops, it is helpful to assume that any lead in the edible portions of food derives from either the atmosphere or the natural lead in soil. Recognizing that some of the lead in soil is of atmospheric origin, the food crop can be seen to contain surface lead (atmospheric) and internal lead (atmospheric and natural).

Based on air concentration and particle size distribution, there is an upper amount of lead that can be deposited on the surfaces of plants during the normally short period of exposure for edible parts. At 0.05 $\mu g/m^3$, a deposition rate of 0.6 $ng/cm^2/day$ is a reasonable value. Consequently, leafy vegetables having a surface area-to-mass ratio of 10:1 cm^2/g and a field exposure time of 20 days might have 120 ng Pb/g fresh weight as surface deposition.

Using the same deposition rate for soil, extrapolated over 50 years of atmospheric lead deposition, gives an upper level of about 1 µg/g soil. Although this amount is small compared to the total amount of lead in soil

(10-25 μg/cm^2), there is an unanswered question of the relative availability of atmospheric and natural lead in soil. It is likely that less than 50% of the lead in soil moisture taken up by plants is of atmospheric origin. Because this source of lead is small, the error introduced by this assumption is negligible.

A recent study by Wolnik et al. (2) of 1500 samples taken from ten crops at a cross section of geographic locations showed that the exposed edible portions of food crops have generally higher lead concentrations than underground crops or aboveground crops not subject to extensive deposition. The difference was small, and a deposition rate as low as 0.04 ng/cm^2/day could account for the difference. From these data, we suggest that prior to harvest, the atmospheric contribution to food crops is of the order of 0.03 μg/g fresh weight for exposed crops and 0.002 μg/g fresh weight for underground or non-exposed plants.

By the time food crops reach the table, the lead content has increased substantially. This additional lead may be atmospheric lead added during transportation, handling, and storage, or metallic lead (solder and machine dust) added from cans or processing machinery. Substantial amounts of either atmospheric or metallic lead may also be added in the kitchen. Lead measured in processed foods immediately before canning and after delivery to the supermarket shelf increases from 0.03 μg/g to about 0.25 μg/g when these cans have a lead solder side seam (3). Beyond this metallic lead, small amounts of atmospheric lead are added during processing and preparation.

Lead in meat products may also be atmospheric by way of deposition of forage crops, or metallic, by way of processing and handling. Because of the uncertainty with types of feed given to livestock, the origin of much of this lead and the lead in dairy products remains obscure.

Tables I and II depict the relative contributions of atmospheric and metallic lead in food, showing also that much of the lead that is of undetermined origin is either atmospheric or metallic. Using the typical diet for two-year-old children as determined by Pennington (4), the background consumption of lead in food is 19 μg/day, of which about 52 percent is of atmospheric origin, 33 percent metallic origin, and 12 percent of undetermined origin. Less than 4 percent of the lead in this diet is from natural sources. Adding water and beverages to this diet raises the total consumption of lead to 26 μg/day, with 11 μg/day from atmospheric sources.

Another major source of lead consumption is dust. There are many types of dust with wide ranges of lead concentrations, and there apparently has been no study of the amounts of dust consumed by children. It is likely that a child ingests a minimum of 100 mg of dust per day. Conservatively speaking, it is not unreasonable that a child might consume ten times this amount of dust per day.

Keeping in mind that the baseline estimates of exposure do not include primary or secondary occupational exposure, roadside exposure, or exposure to houses with lead-based paint pigments, it is reasonable to assume that most of the lead in the baseline household and playground dusts is of atmospheric or soil origin.

Data from several sources show that dust in non-urban households ranges from 50 to 500 µg/g, in streets 80 to 130 µg/g, and in non-lead industrial environments about 150 µg/g. In order to assess the impact of dust on children in the baseline category, average concentrations of 300, 90, and 150 µg/g were assumed, and a ratio of 5:4:1 was applied to their relative consumption by children. Using these data, Table III shows the relative impact of dust on atmospheric lead consumption. These calculations show about 90 percent of the dust in the baseline situation is of atmospheric origin.

The final category, inhaled air, represents a minor source of atmospheric lead for humans in a baseline situation. Assuming an ambient air concentration of 0.1 µg/m^3 and an indoor/outdoor ratio of 0.5, the average concentration of inhaled air is 0.05 µg/m^3. A child breathes about 10 m^3/day, giving a total exposure of 0.5 µg/day, all of which is atmospheric. The question of retention of lead in the lungs should be addressed at this point. It appears that only a small fraction of the particles containing lead is trapped in the alveoli. A larger fraction is trapped in the mucus of the air passageways, then transferred to the esophagus and stomach. Some of the particles are exhaled. Taken in the context of the total exposure of humans to lead, the exhaled portion is of little significance.

The total baseline exposure is summarized in Table III, with designations for atmospheric, metallic, and lead of undetermined origin. The figure suggests that with the elimination of atmospheric lead, the exposure on two-year-old children would decline to 20 µg/day, or less, depending of the atmospheric contribution to lead of undetermined origin. This is not the case, however. The immediate elimination of lead from air would probably result in a gradual decline in lead exposure as dust lead concentrations decreased and atmospheric deposition on food crops declined. But much of the lead in soil and soil-related dust will remain for extended periods of time, projecting the decline in exposure to atmospheric lead to a period of decades.

Superimposed on the expected decrease in atmospheric lead is an apparent reduction of lead in food caused by the elimination of cans with lead-soldered side seams. This decrease is probably proceeding more quickly, as the rate-determining factor is the changeover to different cans, a process that may take less than five years.

A final point to be made about the baseline exposure of children is that the exposure of other age groups differs only in the amounts of dust and types of food consumed by each group. The exposure estimates for children are higher because children are presumed to consume more dust than adults.

ADDITIONAL EXPOSURE ABOVE THE BASELINE

Having established the minimum exposure under conditions of low atmospheric concentrations and normal food concentrations, the next question to address is what circumstances can substantially increase the exposure of children. There are several mutually exclusive situations that can

directly increase the exposure on an additive basis. Specifically, a child may live in a house painted with lead-based paints. This house may or may not be in an urban environment, where the ambient air concentration may be 3 to 30 times higher (0.15 to 1.5 $\mu g/m^3$), or near a smelter, where the air concentrations are generally even higher. The child's parents may work in a lead-related industry, which would increase the lead consumption by secondary occupational exposure. The location of the home, type of house paint and parent's occupation are the most sensitive to abrupt increases in lead exposure. For all three cases, the primary cause of the increase can be attributed to dust.

In evaluating the conditions for additive exposure, it is assumed that all other exposure parameters remain the same, that only lead concentrations change in the critical environmental component. The amount of dust consumed, the type of food eaten, and the amount of air and water consumed remain constant between groups.

In an urban environment, the lead concentration of street dust increases from 90 µg/g to about 1000 µg/g and household dust increases from 300 to 1000 µg/g. The total dust lead consumption by the formula used previously (0.05 g household, 0.04 street dust, 0.01 occupational dust) increases to 95 µg/day, or 74 µg/day more than the baseline value. For a house with interior lead paint, the house dust increases to 2000 and street dust remains at 90, giving a dust exposure of 106 µg/day, or 85 µg/day more than baseline. When the house is near a smelter, both street and house dusts commonly exceed 25,000 µg/g, giving an increase of about 2200 µg/day.

Household dust in a secondary occupational setting increases from 300 to about 2400, street dust remaining the same. The total exposure increases to 150 µg/day or about 130 µg/day more than background.

REFERENCES

1. U.S. Environmental Protection Agency, Air Quality Criteria for Lead. Volume II, Chapter 7. External Review Draft. EPA-600/8-83-028A. August, 1983.

2. K. A. Wolnik, E. L. Fricke, S. G. Capar, G. L. Broude, M. W. Meyer, R. D. Satzger, E. Bonnin, "Elements in major raw agricultural crops in the United States. I: Cadmium and lead in lettuce, peanuts, potatoes, soybeans, sweet corn and wheat." J. Agric. Food Chem. 31:1240-1244 (1983).

3. K. W. Boyer, R. D. Johnson, "Levels of lead, cadmium, and zinc in selected canned foods" (1980/1981). J. Food Saf. 4:207-222 (1982).

4. J. A. T. Pennington, "Revision of the total diet study food list and diets." J. Am. Diet. Assoc. 82:166-173 (1983).

Table I. Lead Concentrations in Foods and Beverages Weighted According to Consumption

	Total Pb Consumed µg/g	Atmospheric Pb µg/g	Solder and Other Metallic Pb µg/g	Other Types of Pb µg/g
Dairy products	0.0064	0.005	--	0.0014
Meat products	0.025	0.02	0.002	0.003
Food crops	0.025	0.016	--	0.009
Canned foods	0.115	0.016	0.09	0.009
Canned juices	0.041	0.0015	0.037	0.0025
Frozen juices	0.009	0.0015	0.005	0.0025
Soda	0.013	0.0015	0.009	0.0025
Water†	0.007	0.0015	0.003	0.0025

*Includes natural lead and atmospheric lead in soil, pigment lead, and atmospheric/metallic lead not otherwise accounted for in columns 2 and 3.

†Includes coffee, tea, and drink mixes.

Table II. Sources of Lead in the Diet of 2 Year-Old Children

	Total Consumed (g/day)	Total Pb Consumed (µg/day)	Atmospheric Pb (µg/day)	Soldered Metallic Pb (µg/day)	Other Types of Pb* (µg/day)
Dairy products	379	2.4	1.9	--	0.5
Meat products	118	3.0	2.4	0.2	0.4
Food crops	290	7.3	4.6	--	2.7
Canned foods	65	7.5	1.0	5.9	0.6
Canned juices	54	2.2	0.1	2.0	0.1
Frozen juices	65	0.6	0.1	0.3	0.2
Soda	70	0.9	0.1	0.6	0.2
Water†	434	3.0	0.7	1.3	1.0
Total		26.9	10.9	10.3	5.7
% of Total		100.0%	40.5%	38.3%	21.2%

*Includes natural lead and atmospheric lead in soil, pigment lead, and atmospheric/metallic lead not otherwise accounted for in columns 4 and 5.

†Includes coffee, tea, and drink mixes.

Table III. Summary of Baseline Exposures to Lead for 2 Year-Old Children. Data are in µg/day.

	Total Pb Consumed	Atmospheric Pb	Solder and other Metallic Pb	Other Types of Pb*
Inhaled air	0.5	0.5	--	--
Food and beverages	26.9	10.9	10.3	5.7
Dust	21.0	19.0	--	2.0
Total	48.4	30.4	10.3	7.7
% of Total	100.0%	62.8%	21.3%	15.9%

*Includes natural lead and atmospheric lead in soil, pigment lead, and atmospheric/metallic lead not otherwise accounted for in columns 2 and 3.